

# **MASTER OF SCIENCE IN ELECTRICAL ENGINEERING**

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## **EVALUATION OF ALTERNATIVE COMMUNICATION SCHEMES USING ENVIRONMENTALLY ADAPTIVE ALGORITHMS**

**Christos Athanasiou-Lieutenant, Hellenic Navy**

**Diploma, Hellenic Naval Academy, 1992**

**Master of Science in Electrical Engineering-June 2001**

**Master of Science in Applied Physics-June 2001**

**Advisors: Andrés Larraza, Department of Physics**

**Kevin B. Smith, Department of Physics**

**Monique P. Fargues, Department of Electrical and Computer Engineering**

Time-varying multipath propagation in a shallow underwater environment causes intersymbol interference in high-speed underwater acoustic (UWA) communications. Combating this effect is considered to be the most challenging task requiring large adaptive filters and increasing the computational burden at the receiver end.

This thesis presents results of an in-tank experiment and data analysis performed off-line to examine, evaluate, and compare the robustness of Time-Reversal Approach to Communications (TRAC) and the Matched Environment Signaling Scheme (MESS) in different conditions, such as noise, surface waves and range changes between the receiver and transmitter. Both methods examined can environmentally adapt the acoustic propagation effects of a UWA channel. The MESS method provides a communications solution with increased computational complexity at the receiver end but gives higher data rates and is more robust to the presence of noise, surface waves, and range changes than the TRAC method. On the other hand, the TRAC method manages to accomplish secure communications with low computational complexity at the receiver.

**DoD KEY TECHNOLOGY AREA:** Command, Control and Communications

**KEYWORDS:** Time Reversal Acoustics, Acoustic Communications, Acoustic Signal Processing, Acoustic Telemetry

## **SECURITY OF CODE-DIVISION MULTIPLE ACCESS (U)**

**Z. Anna Entrichel-National Security Agency**

**B.S., North Carolina State University, 1993**

**Master of Science in Electrical Engineering-June 2001**

**Advisors: R. Clark Robertson, Department of Electrical and Computer Engineering**

**William W. Brandenstein, National Security Agency**

**Second Reader: Tri T. Ha, Department of Electrical and Computer Engineering**

With the shift of the defense industry from developing Government-off-the-shelf (GOTS) equipment to engineering current and new commercial products and technology into pre-existing and new government communication products along with the growing popularity of wireless mobile communication, a look at the security of code-division multiple access (CDMA) – a current and future wireless multiple access technology – in the context of the tactical battlefield is the focus of this paper.

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After identifying the security weaknesses of CDMA in the context of the Global Information Grid (GIG) – an environment to support tactical communication networks – technologies to minimize or overcome the vulnerabilities are presented for the tactical commander to employ or implement.

Additionally, the effect of pulse jamming on a IS-95 like CDMA system is analyzed. Graphs are provided to show how the probability of bit error due to the pulse jammer is directly influence by the power of the transmitter.

**DoD KEY TECHNOLOGY AREAS:** Other (Global Information Grid, Wireless Communication)

**KEYWORDS:** Code-Division Multiple Access (CDMA), Global Information Grid (GIG), Tactical Battlefield, Security Services, Hard Decision Decoding

### **AN IMPROVED MAGNETIC, ANGLE RATE, GRAVITY (MARG) BODY TRACKING SYSTEM**

**Pierre G. Hollis-Captain, United States Marine Corps**

**B.S., Rensselaer Polytechnic Institute, 1993**

**Master of Science in Electrical Engineering-June 2001**

**Electrical Engineer-June 2001**

**Committee Chair: Xiaoping Yun, Department of Electrical and Computer Engineering**

**Committee Members: Sherif Michael, Department of Electrical and Computer Engineering**

**Eric R. Bachmann, Department of Computer Science**

This thesis proposes the design of an improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System. The current MARG Body Tracking System is limited to tracking three limb-segments. The MARG sensors are physically connected to a desktop computer by cables.

In this thesis, a multiplexing circuit was implemented to allow tracking of 15 limb-segments. Processing was moved from a desktop computer to a wearable computer and wireless communication was implemented using an IEEE 802.11b spread spectrum wireless LAN. The resultant system is able to track the entire human body and is untethered. The range of the system is the same as that of the wireless LAN which can be extended with the use of repeaters. This thesis work will ultimately allow human insertion into virtual environments for training and other applications.

**DoD KEY TECHNOLOGY AREA:** Computing and Software, Human System Interface, Sensors

**KEYWORDS:** Human Body Tracking

### **ANALYSIS OF M-JPEG VIDEO OVER AN ATM NETWORK**

**Albert C. Kinney-Lieutenant Commander, United States Navy**

**B.S., U.S. Naval Academy, 1989**

**Master of Science in Electrical Engineering-June 2001**

**Advisor: John McEachen, Department of Electrical and Computer Engineering**

**Second Reader: Murali Tummala, Department of Electrical and Computer Engineering**

With the emergence of a network-centric philosophy of military operations, the behavior of video applications over resource-constrained information networks is of increasing interest in the development of future naval information systems. This thesis analyzes the impact of compression, delay variance, and channel noise on perceived networked video quality using commercially available off-the-shelf equipment and software. An experimental packet video laboratory is developed for quantitative and qualitative analysis of Motion JPEG video transmitted over a constrained Asynchronous Transfer Mode (ATM) network. Bandwidth profile analysis for various types of video points out the impracticality of ATM bandwidth and cell delay management algorithms for mainstream video applications such as entertainment and distance learning. Additionally, functional limitations of individual laboratory components are identified for consideration in the planning of future experimental work.

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**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communication

**KEYWORDS:** ATM, Protocol, Motion JPEG, Packet Video, Communications

### VLSI DESIGN OF SINE/COSINE LOOKUP TABLE FOR USE WITH DIGITAL IMAGE SYNTHESIZER ASIC

Kevin M. Kirin-Lieutenant, United States Navy  
B.S., United States Naval Academy, 1994

Master of Science in Electrical Engineering-June 2001

Advisors: Douglas J. Fouts, Department of Electrical and Computer Engineering  
Phillip E. Pace, Department of Electrical and Computer Engineering

This thesis documents the circuit design, simulation, and integrated circuit mask layout of the sine/cosine Lookup Table (LUT) to be integrated into the Digital image Synthesizer (DIS) ASIC. The DIS is a single-chip false target radar image generator to be used in countering wide-band imaging radars. The purpose of the LUT is to take the 5-bit input from the phase rotation adder of the DIS and digitally generate the In-phase (I) and Quadrature (Q) signals to form the false target radar returns.

The first part of the design includes an extensive analysis to determine the optimal resolution for the LUT ROM. The design proceeds with the circuit design of an 8-bit resolution sine/cosine LUT. SPICE Net-lists are generated from the circuit schematics in order to run simulations to prove logic validity and determine time delays. Mask layout of the verified design is constructed using a CMOS 0.18 micron process utilizing deep sub-micron technology. Finally, the mask layout design is verified by ensuring all design rule checks (DRCs) and layout versus schematic (LVS) checks are satisfied. In addition, recommendations are provided to assist other DIS project members in effectively using the aforementioned layout process in the continuing design and layout of the DIS ASIC.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Electronic Warfare

**KEYWORDS:** Digital Image Synthesizer, VLSI, ASIC, CMOS, Lookup Table, ROM, Chip Design

### TIME DELAY ESTIMATION FOR UNDERWATER SIGNALS AND APPLICATION TO LOCALIZATION

Stefanos D. Kouteas-Lieutenant Junior Grade, Hellenic Navy  
B.S., Hellenic Naval Academy, 1992

Master of Science in Engineering Acoustics-June 2001

Master of Science in Electrical Engineering-June 2001

Advisors: Charles W. Therrien, Department of Electrical and Computer Engineering  
Kevin B. Smith, Department of Physics

The problem of time difference of arrival (TDOA) is important in underwater acoustics for both passive and active sonar. Classical approaches to this problem are based on generalized cross-correlation (GCC) methods implemented in the frequency domain. After appropriate weighting of the cross spectral data in the frequency domain, an inverse discrete Fourier transform (IDFT) is performed and the peak of the resulting GCC function is located in the time domain.

This thesis shows that the cross-spectrum of the data satisfies an appropriate signal subspace model; therefore the IDFT can be replaced with a signal subspace technique such as MUSIC. The result is an enhanced ability to locate the peak. Further, application of methods such as root-MUSIC or ESPRIT produce direct numerical estimates for TDOA without the need to search for a peak. Results are presented for an extensive set of simulations using both synthetic signal data and data from a ocean acoustic propagation model (MMPE). Results are further presented for an application of the new method to target localization and tracking. In all cases results are compared using both the new methods and the classical methods.

**DoD KEY TECHNOLOGY AREAS:** Other (Underwater Acoustics, Signal Processing)

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**KEYWORDS:** Time Difference of Arrival, Subspace Methods, Generalized Cross-Correlation, Localization

### **SHIPBOARD WIRELESS NETWORK APPLICATIONS**

**Tung T. Ly-Lieutenant, United States Coast Guard**

**B.S., Virginia Tech, 1991**

**Master of Science in Electrical Engineering-June 2001**

**Advisor: Xiaoping Yun, Department of Electrical and Computer Engineering**

**Second Reader: John C. McEachen, Department of Electrical and Computer Engineering**

Recently, the need to leverage technologies for better utilizing valuable personnel resources has become more important. Wireless Local Area Networks (WLANs) have been shown to be an enabling technology that allows companies in commercial industry to become more productive. Research has been conducted at the Naval Postgraduate School to determine how this technology can be utilized to help the Navy perform shipboard operations more efficiently.

Continuing the work of previous theses at NPS, the objective of this thesis is threefold. First, WLAN standards are examined. Second, laboratory tests are conducted to determine the performance of WLANs in which access points are configured as radio repeaters. Finally, a web-based application is developed for shipboard gage calibrations. The application automates major portion of gage calibration process by allowing technicians to submit and to view the calibration results using a web browser through wired or wireless LANs.

Testing results show that the access points from certain vendors are able to operate as radio repeaters and still provide adequate performance. Repeater functionality is not specified in IEEE 801.11 standards, and its implementation is vendor specific. Demonstration of the web-based gage calibration application shows that it is effective in improving calibration efficiency.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** IEEE 802.11, Wireless Local Area Network, Active Server Pages, Internet Database

### **LOCALIZATION OF WIRELESS COMMUNICATION EMITTERS USING TIME DIFFERENCE OF ARRIVAL (TDOA) METHODS IN NOISY CHANNELS**

**Spiros D. Mantis-Lieutenant, Hellenic Navy**

**B.S., Hellenic Naval Academy, 1991**

**Master of Science in Electrical Engineering-June 2001**

**Master of Science in Systems Engineering-June 2001**

**Advisors: Ralph Hippenstiel, Department of Electrical and Computer Engineering**

**David C. Jenn, Department of Electrical and Computer Engineering**

**Tri T. Ha, Department of Electrical and Computer Engineering**

The ability to provide position information of wireless emitters comprises a very important communication tool and has extremely valuable applications to military as well as civilian life. GSM is the most popular method of modulation adopted around the world, for mobile telephony. This thesis is focused on the Time Difference Of Arrival (TDOA) estimation, applied to GSM signals, in noisy channels. Improvements in denoising, in conjunction with wavelet processing, are proposed for estimating the TDOA of signals received at two spatially separated sensors. Wavelet denoising based on a modified maximum likelihood method and a higher order moment method is proposed, to improve the performance. A numerical evaluation of the methods, when unequal SNR conditions prevail, is presented. The performance of the proposed denoising methods in a jamming environment is also addressed. Simple excision schemes to improve the performance when jamming is present, are evaluated. Simulation results indicate good performance of the methods and improved estimates relative to the ones obtained using no denoising. Jamming presence degrades the performance but still the extracted estimates are improved.

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**DoD KEY TECHNOLOGY AREAS:** Electronics, Electronic Warfare

**KEYWORDS:** Global System for Mobile (GSM), Time Difference Of Arrival (TDOA), Wavelet Denoising, Jamming, Emitters Localization

### **EFFECTIVENESS OF THE EA-6B AIRCRAFT STAND-OFF JAMMING AGAINST THREAT AND EARLY WARNING RADAR DURING OPERATION ALLIED FORCE IN SERBIA, AND OPERATIONS NORTHERN AND SOUTHERN WATCH IN IRAQ**

**Eugene L. Reinhard-DoD Civilian**

**B.S.E.E., Purdue University, 1985**

**M.S., St. Mary's University, 1991**

**Master of Science in Electrical Engineering-June 2001**

**Advisors: Phillip E. Pace, Department of Electrical and Computer Engineering**

**Mark A. Kanko, Air Force Information Warfare Center**

This thesis addresses the jamming effectiveness of electronic attack (EA) operations of the EA-6B against early warning (EW) and threat radar during Operation ALLIED FORCE (OAF) from March-June 1999 and Operations NORTHERN WATCH (ONW) and SOUTHERN WATCH (OSW) from July-August 2000. Effectiveness was determined by examining confirmation from all-source intelligence regarding events where jamming was used against targeted radar to degrade their detectability or tracking of strike aircraft. In the absence of confirmation data, the EA-targeting effectiveness was resolved by modeling individual EA-targeting incidents and analyzing whether striker aircraft were protected from enemy radar. In-depth analysis of EA-6B incidents were selected based on the post-mission reports from the EA-6B, strike aircraft, and other reconnaissance and surveillance sources. For OAF, ONW, and OSW, 20 EA-6B incidents were modeled for in-depth analysis. The limited sample size and the inability to always correlate all-source intelligence to an event timeframe impacted the results. The Improved Many-on-Many (IMOM) model was used to model the radar and Tactical Jamming System. The conclusions were based on the post-incident mission analysis, all-source intelligence correlation to an incident recreation, and the theoretical calculation of expected jamming effectiveness against radar systems.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare

**KEYWORDS:** EA-6B, AN/ALQ-99, Tactical Jamming System, Air War Over Serbia (AWOS), Operation ALLIED FORCE (OAF), Operation NORTHERN WATCH (ONW), Operation SOUTHERN WATCH (OSW), Serbia, Iraq, Electronic Attack, Targeting

